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ULTRASONIC RE-INSPECTION OF BLISTERED BHWP PLATES A-F

Report No. 87-97-K

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ABSTRACT

Ultrasonic inspection of seven sections of blistered plate was performed using first a robot with waterjet, and second a conventional contact system. The results confirmed the wall thickness data generated by BHWP personnel, both for blister detection and for depth measurements, within reasonable error limits.

job	file	date	report no.
81-180-550	826.14	May 13, 1987	87-97-K

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EXECUTIVE SUMMARY

ULTRASONIC RE-INSPECTION OF BLISTERED BHWP PLATES A-F

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Six sections of blistered plate were supplied by BHWP to (1) confirm station results using wall-thickness meters, and (2) to be mapped for fracture mechanics testing. A seventh plate was supplied by Research. The plates were ultrasonically scanned, first using a robot with waterjet, and later using a conventional mechanized contact system. The robotic system showed potential, but had problems mapping the surface contours so the plates were scanned using B-scans and C-scans with the contact probe. The C-scans showed that the BHWP had detected all blisters of any significance, and the two sets of data correlated well. Blister depth measurements using B-scans gave similar results to the BHWP data, within an error of ± 1 mm.

JAB
JB

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To Mr. G.D. Davidson
Acting Manager
Bruce Heavy Water Plant

ULTRASONIC RE-INSPECTION OF BLISTERED BHWP PLATES A-F

1.0 INTRODUCTION

Several samples of blister Bruce Heavy Water Plant (BHWP) plate were removed as part of a project to evaluate the properties of blistered vessels (see BHWP EWR No. 01138). The plates were examined ultrasonically by BHWP personnel using a conventional wall-thickness measurement device (Krautkramer DM-2) to locate damaged areas and measure blister depths. The plates were re-examined at Research to 1) confirm the BHWP results, and 2) to map the plates so blistered sections could be removed for Fracture Mechanics testing.

The plates came from BHWP absorber tower E1. Six sections labelled A-F were supplied to the NDE unit at Research. Each had a grid marked on it, typically 250 mm square, which covered most of the plate. Plate F was much larger, and had a grid approximately 250 mm by 460 mm. The grid area of plate F was cut out so the relevant section could fit in the waterbath. Each plate had a number of 12 mm diameter flat bottomed holes (FBH) drilled half way through the wall to act as ultrasonic markers. Table 1 gives the approximate location of each of the markers. The outside surface of plate F was sandblasted to improve coupling. Besides the plates, the BHWP also supplied wall-thickness data on the grid areas for correlation.

Fracture Mechanics required sections of plate material with blisters in the centre region of the plate for testing. Since most of the plates showed relatively low bulk blister density (see Section 4 below), a section of BHWP plate remaining in Research from a previous examination was also scanned. This plate came from the same tower, and was labelled C2. In this report, it is subsequently called the Research plate. This plate was approximately 125 mm by 310 mm. Several 6 mm diameter markers were drilled into this plate.

2.0 INSPECTION TECHNOLOGY

Two types of inspection systems were used. Initially a system based on the PUMA robot was tried, but this was not successful (see section 3 below). Subsequently, a more conventional contact technique was used, using a gimballed probe and immersion tank.

2.1 Robot Inspection System

This system is being developed as part of the nuclear waste fuel management program to demonstrate the feasibility of remote inspection of cylindrical titanium diffusion bond welds/1/. It uses the Research PUMA 560 robot, controlled by an IBM-PC compatible computer. The ultrasonics consists of an EPOCH 2002 ultrasonic flaw detector, with a waterjet and probe, in contrast to the usual contact coupling mechanism. The water for coupling the waterjet is pumped up from a bath and recirculated.

Initially, the operator positions the robot close to the plate to be inspected, with a reflected signal from the frontwall in the flaw detector's gate. Then the computer instructs the robot to twist its wrist twice to maximize the reflected signal amplitude from the frontwall. The computer records the angle of maximum amplitude ie. the orientation of the surface. Then the robot moves the probe forwards towards the plate until the signal is half out of the flaw detector's gate. This gives the location of the point on the plate surface. Then the robot moves on to the next point until it has mapped a pre-specified line of points. At the moment, this procedure is slow and only suitable for vertical surfaces, but the arrival of a contact sensor should allow the mapping to be used for any shaped surface.

When the line of points has been mapped, the robot returns to the start position to scan the component for defects. The gate position and amplitude are adjusted if necessary, and the robot performs a conventional C-scan on the component, also using the waterjet. At no time does the robot or probe touch the component. The scanning is performed in a series of vertical sweeps, each starting from one of the mapped points. This approach assumes the component is accurately vertical, though this limitation should be overcome soon.

Previous robotic inspections of BHWP plate used an Apple computer, which developed a mathematical equation of the surface contour for scanning/2/, rather than mapping and memorizing the surface contours.

2.2 Contact Inspection

Contact inspections were performed using a 5 MHz, 12.7 mm active element probe mounted on a thick plastic contact shoe containing a concave water-filled lens for focussing. The plastic shoe was mounted on a gimballed holder for surface tracking. The plates were placed in an immersion tank under water, and scanned in x and y directions as usual. The scanning tank was controlled by an Apple II Plus computer, which also displayed and recorded data. This procedure is similar to previous BHWP inspections, except water was used for the couplant, not Hamikleer. Either C-scans (area amplitude contours) or B-scans (through thickness plots) could be performed. Typically, large area C-scans were performed, followed by B-scans on areas of special interest.

3.0 RESULTS FROM ROBOTIC SCANS

Figure 1 shows a general photograph of the robot scanning plate B, and Figure 2 a close-up of the waterjet. Several attempts were made to scan this plate, but overall the approach was unsuccessful due to problems with the mapping stage. The mapping process depends on the maximum signal amplitude occurring at the normal

to the surface, which did occur on the smooth titanium nuclear waste container. However, the rougher surface of the BHWP plate generated a fluctuating signal amplitude, which sufficiently "confused" the computer that often it recorded the maximum well away from the normal. This seriously affected the subsequent C-scans, sending stray backwall signals into the gate. This problem should be totally eliminated by using a new contact sensor currently on order.

Despite this mapping problem, and a couple of minor software ones, the robotic inspection process repeatably detected a reflector in plate B, indicating that the process has potential. Work will continue on the nuclear waste project over the summer with the return of the computer student, who will include the new sensor and modify the software. The advantages of the robotic approach are that in principle it can be used to:

(1) scan components of any geometry;

(2) perform the inspections remotely after set-up; and,

(3) perform inspections at operating temperatures (though the temperature properties of the sensor will need investigating). The limited transportability of the robot can be surmounted in principle by putting it on wheels/tracks. Overall, the robot offers a relatively low cost, versatile option.

4.0 RESULTS FROM CONTACT INSPECTIONS

C-scans of plate A showed several areas of blistering. Figure 3 is a B-scan along the "F" line on plate A, showing two blisters with estimated depths from front wall (outside surface) marked. Figure 4 shows a B-scan along the "I" line with one near-backwall blister marked.

Figure 5 shows a C-scan of plate B, with several blisters present. The plate was rescanned (Figure 6) with the gate set to exclude the region near the inside surface, which showed all the blisters to be near surface. This was confirmed by performing a series of B-scans along the alphabet lines. Figure 7 shows a sample B-scan along the paint line labelled "C", with three near back-surface blisters detected.

Figure 8 shows a C-scan of plate C, which contained relatively few blisters. A re-scan excluding the near back-surface region detected no blisters, showing that all blisters were near-surface. Figure 9 is a C-scan of plate D, showing a low blister concentration. Rescanning showed that the blister labelled was not near-surface. Figure 10 is a C-scan of plate E, showing a very low blister concentration. In contrast the C-scan of the grid area on plate F showed a fairly high concentration of blisters, many running in strings along the plate (Figure 11). Most of these were not near surface.

Figure 12 is a composite C-scan of the Research plate, showing very extensive blistering. Re-scanning showed that most of these blisters were not near-surface. The plate was also re-scanned with the backwall signal gated to detect areas of lack-of-backwall-signal (Figure 13). Areas where neither reflections from blisters nor backwall signals are observed suggest either (1) stepwise cracking, or (2) exceptionally rough or angled front surfaces. Consequently a series of B-scans were per-

formed through such an area marked in Figures 12 and 13. Figure 14 is a sample B-scan, showing blistering and step-wise cracking. (Note that loss-of-backwall C-scans are not the best method of detecting step-wise cracking.)

5.0 CORRELATION WITH BHWP RESULTS

5.1 Correlation With C-Scans

The BHWP data was supplied as a grid with the minimum recorded depth in each 25 mm, as per BHWP practice. Two approaches were used to correlate the BHWP and Research data. First, the C-scans were compared with the BHWP grids to determine if all the blisters detected by Research were also "detected" by BHWP. The correlation here was generally good; for example, on plate C, blisters were detected on grids D8 and C1, say, while lower wall thicknesses were recorded by BHWP in C8/D7 and C1/2.

There were some minor anomalies, eg. on plate E, BHWP recorded a reduced depth in square E4, but a blister was not detected by Research. This difference could occur if the blister was very small. As another example, on plate D the reduced depth recorded by BHWP in squares F1 and F2 correlated well with Figure 9. Overall, there were no significant anomolies between the two sets of data. Research did not detect any significant blisters missed by the BHWP. No BHWP data was available for plate F.

5.2 Correlation With B-Scans

The second approach involved comparing measured depths of blisters from selected B-scans with BHWP minimum recorded depths. B-scan depth measurements were performed by calculating the ratio frontwall-blister to frontwall-backwall. Figures 3,4 and 7 show sample results. These results are within 1 mm of the corresponding BHWP data, indicating a good correlation. There are several possible sources of this small error, mostly related to B-scans. First the B-scans may not pass over the maximum depth of the blisters. Second, B-scan measurements are done from the chart, so the results will depend on the precise measurement location. Third, wall thicknesses appear to vary slightly. Lastly, the correlation assumes the DM-2 was correctly set up. Overall, the BHWP data is likely to be more accurate than the Research B-scans for actual wall-thickness measurements; B-scans have other advantages, eg they image the blisters and reduce false information.

6.0 CONCLUSIONS

(1) A general-purpose robot offers potential for remote inspection of curved BHWP plate, though the current system requires further hardware and development.

(2) Plates B, C, D, and E showed only moderate to light blistering, and almost all of this was near the back surface.

(3) The painted grid area on plate F showed extensive blistering, much of which was not near-surface.

(4) *The Research plate showed very extensive blistering, also not near-surface. Through thickness B-scans showed some step-wise cracking.*

(5) *The Research C-scans showed that the BHWP detected all blisters of any significance, and the two sets of data correlated well.*

(6) *Blister depth measurements using B-scans gave similar results to the BHWP data, within an error of 1 mm.*

7.0 RECOMMENDATION

If the BHWP is interested in a remote, robotic system for inspecting complex curved components, they should supply one or more sample plates this summer for further development work by Research.

8.0 ACKNOWLEDGEMENT

Mr A.L. Allen assisted with the Research inspections.

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1. *D.J. Dowker and M.D.C. Moles, Ontario Hydro Research Division report in progress.*

2. *A.L. Allen, E.G. de Buda and M.D.C. Moles, Ontario Hydro Research Division Report No. 84-235-K, August 31, 1984.*

TABLE 1

Approximate Locations of FBH Markers on Plates A-F

Plate	Marker Locations
A	K1/K10/H5....[1]
B	A2/A9/J2/J9-10[2]
C	A-B1/A9-10/J-K1/J-K10
D	A-B1-2/A-B9/K1/K9
E	B2/B10/I-J2/J11
F	B2/A10/A18/B5/L1-2/K10/L18

FIGURE 1
PHOTO OF PUMA ROBOT
SCANNING PLATE B

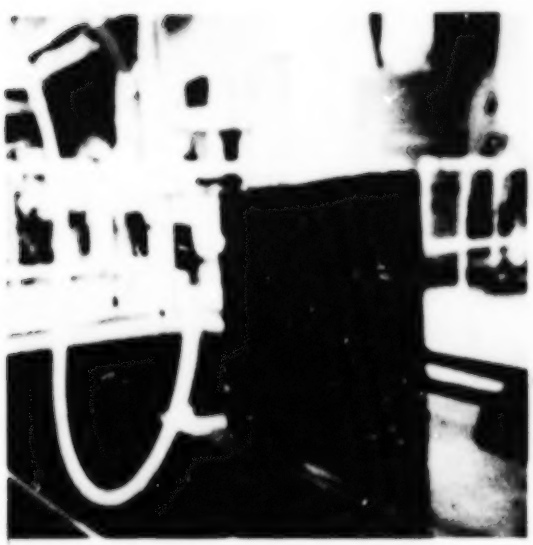

FIGURE 2
CLOSE-UP OF WATERJET

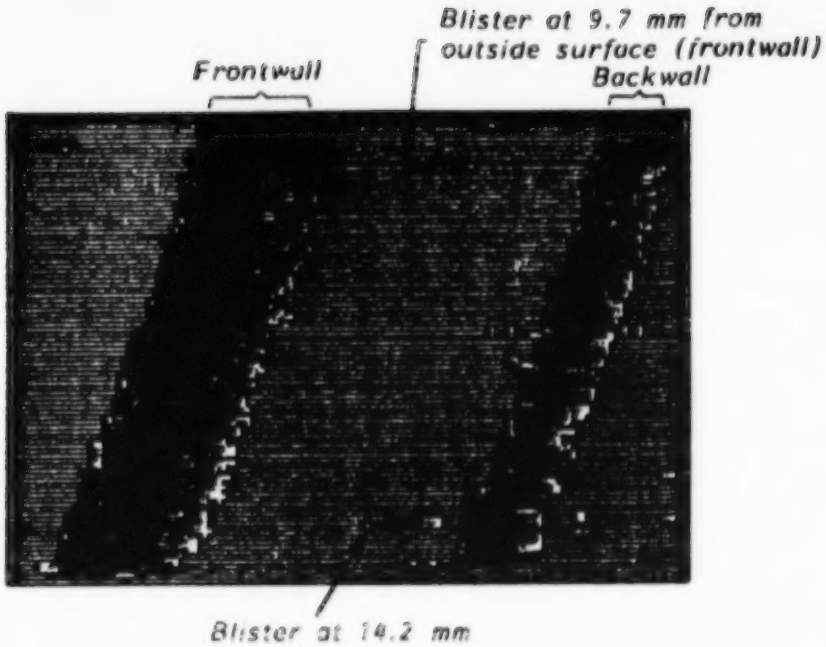

FIGURE 3
BLISTERS ALONG LINE F ON PLATE A,
IMAGED USING A B-SCAN

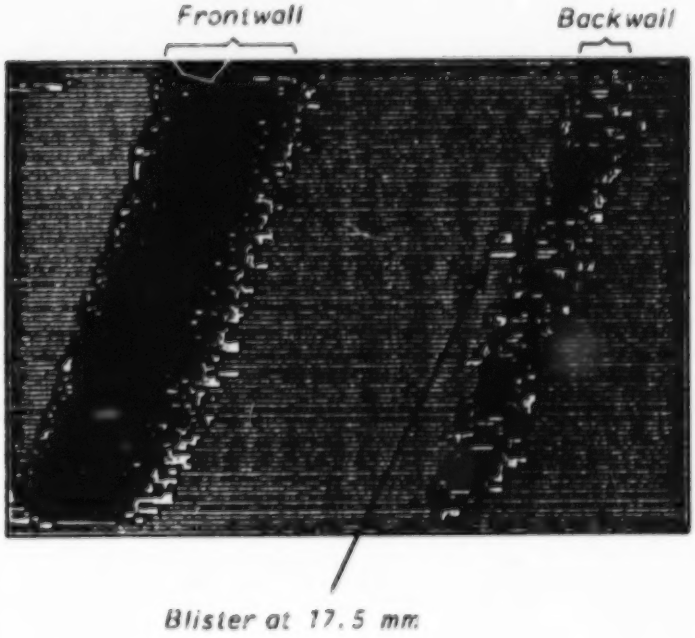

FIGURE 4
B-SCAN ALONG LINE I ON PLATE A

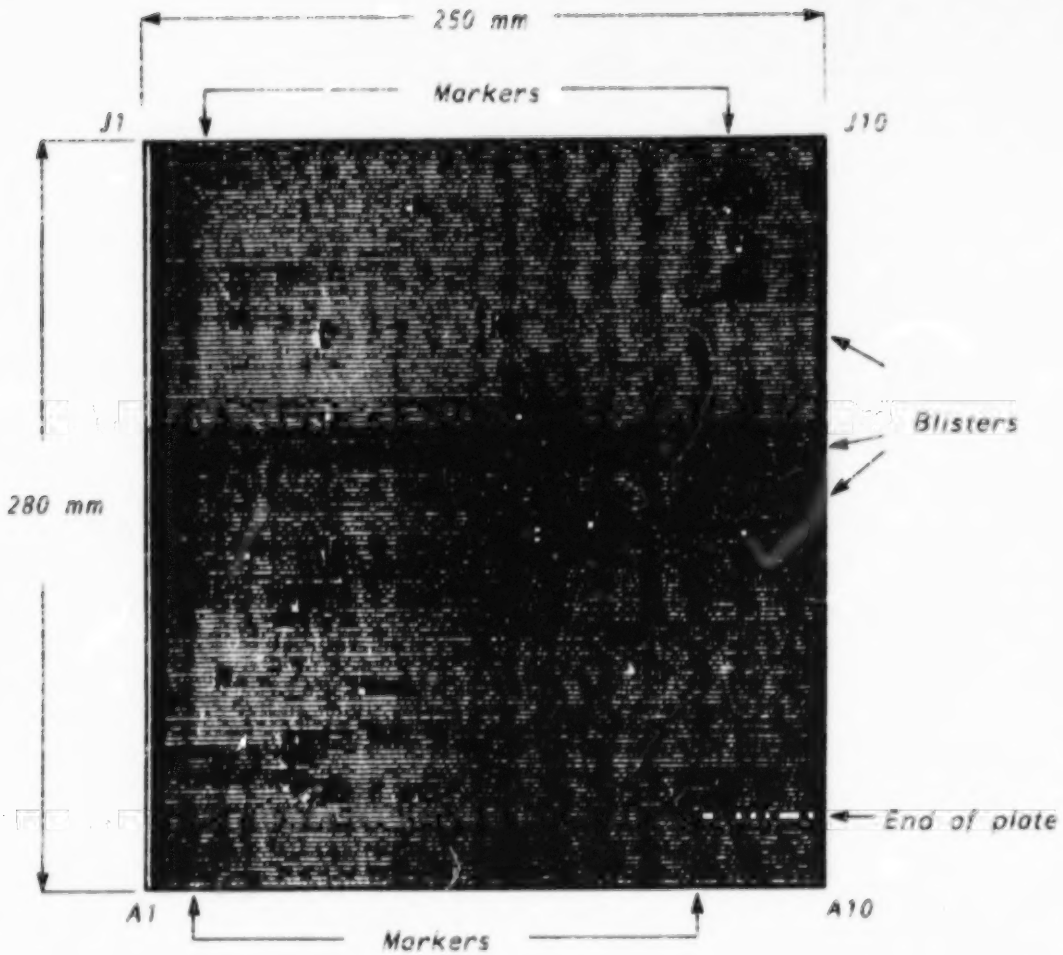

FIGURE 5

C-SCAN OF PLATE B, SHOWING
FOUR MARKERS AND BLISTERS
(AT 20 dB)

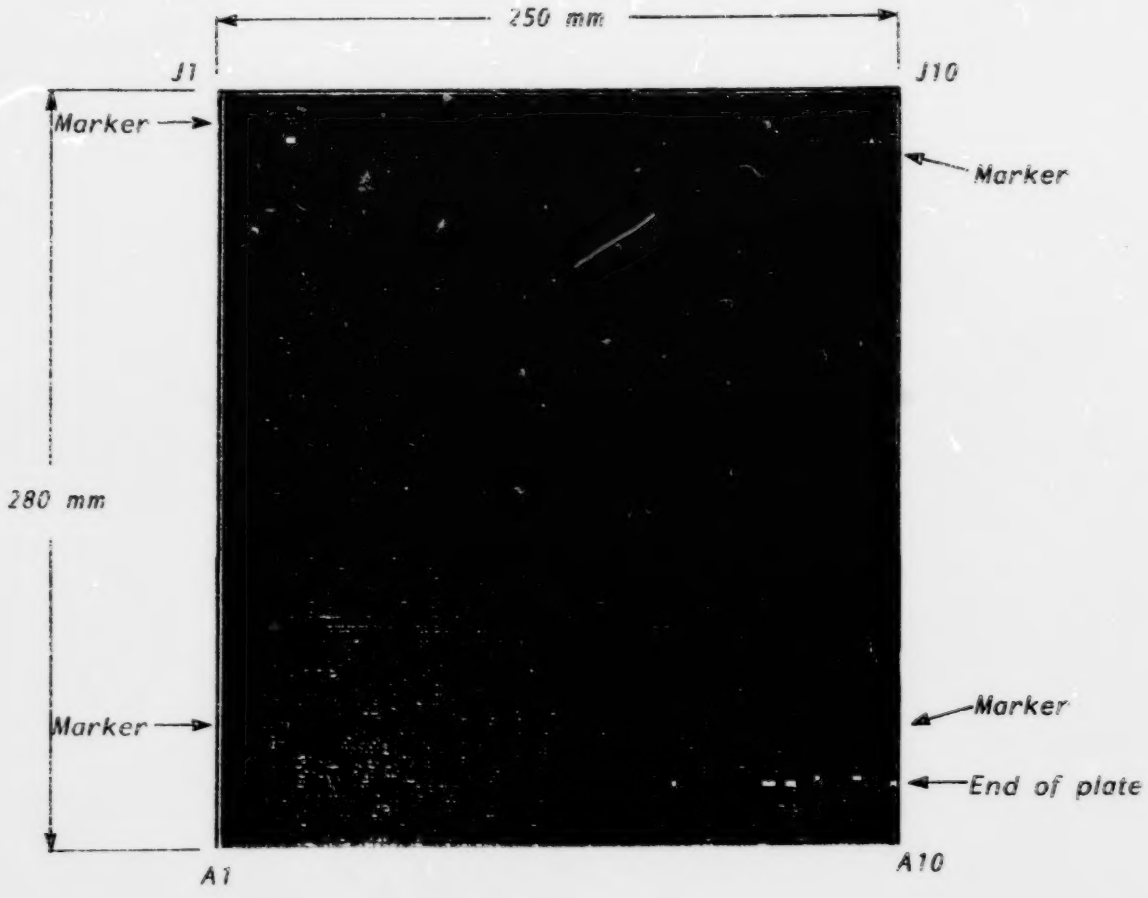

FIGURE 6

C-SCAN OF PLATE B WITH BACKWALL
REGION GATED OUT, SHOWING
FOUR MARKERS ONLY

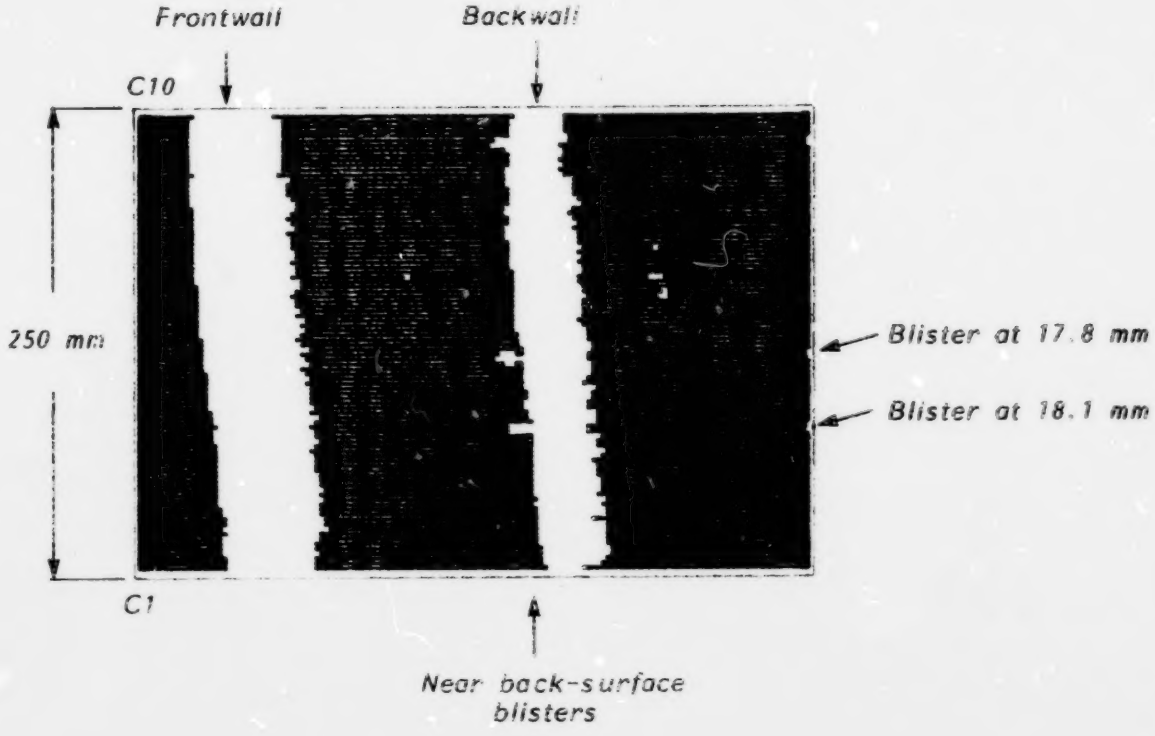

FIGURE 7

SAMPLE B-SCAN THROUGH PLATE B ALONG C LINE, SHOWING THREE NEAR SURFACE BLISTERS

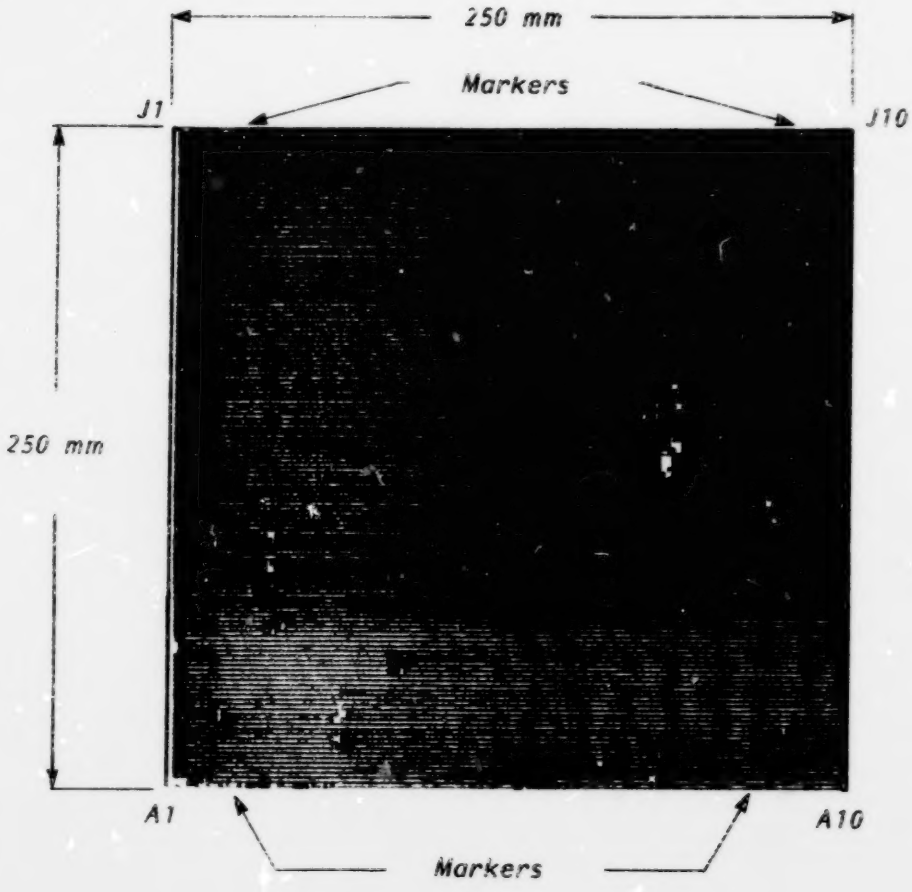

FIGURE 8
C-SCAN OF PLATE C, SHOWING
FOUR MARKERS AND NEAR
INSIDE SURFACE BLISTERS

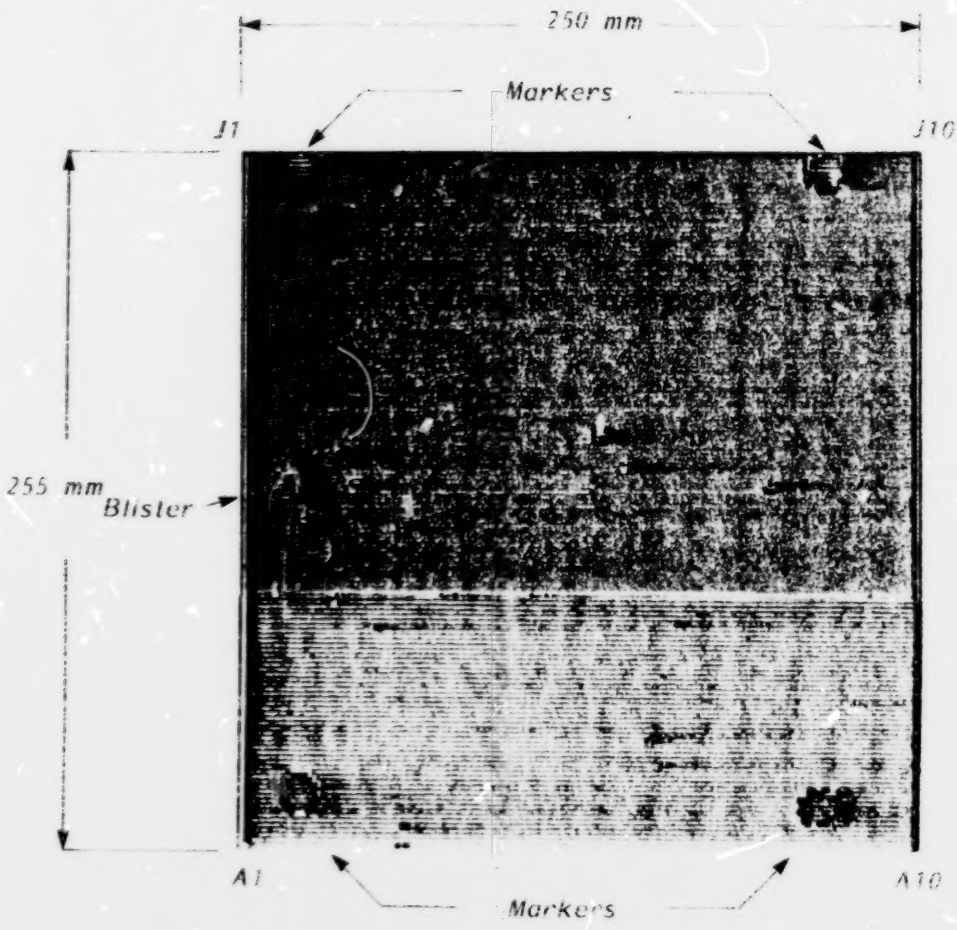

FIGURE 9
C SCAN OF PLATE D, SHOWINC FOUR MARKERS. BLISTER MARKED WAS NOT NEAR SURFACE

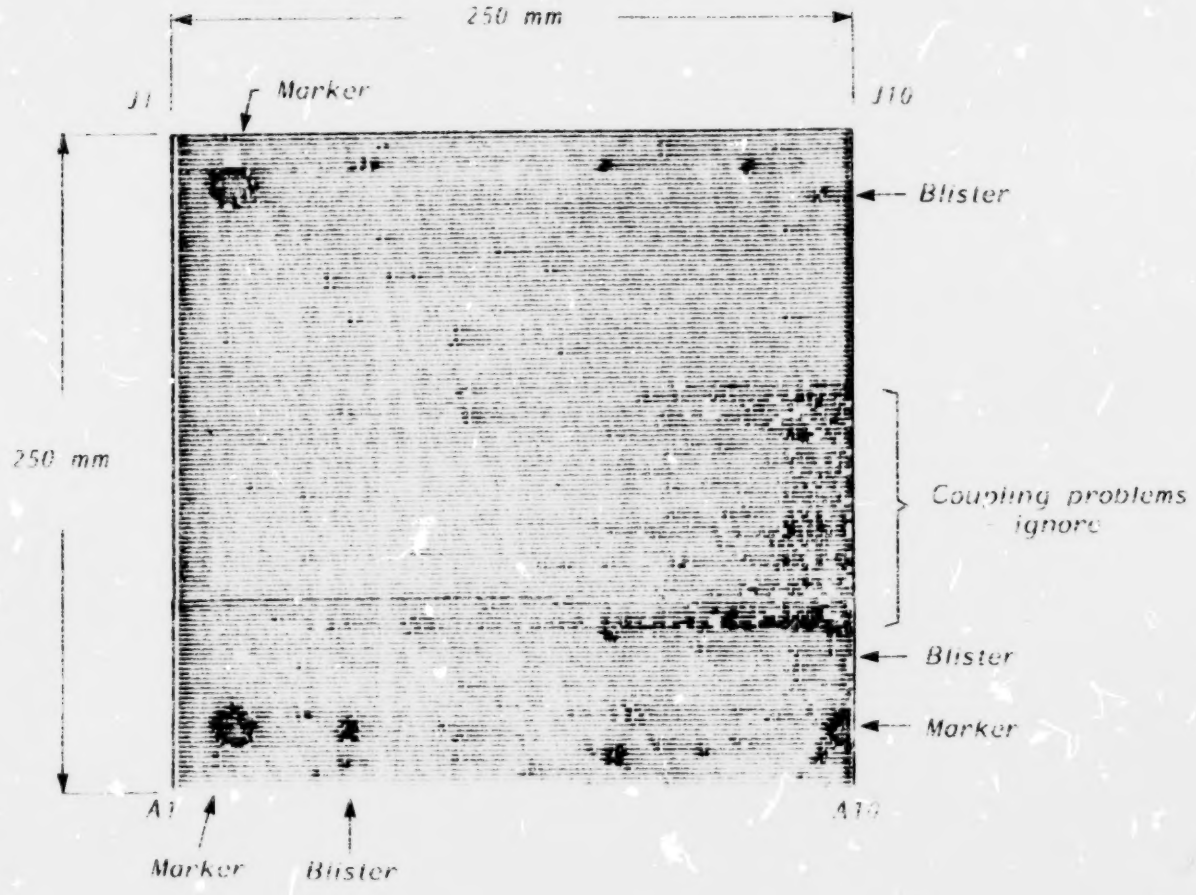

FIGURE 10
C SCAN OF PLATE E AT 20 dB
SHOWING MINIMAL BLISTERING

174569-RD

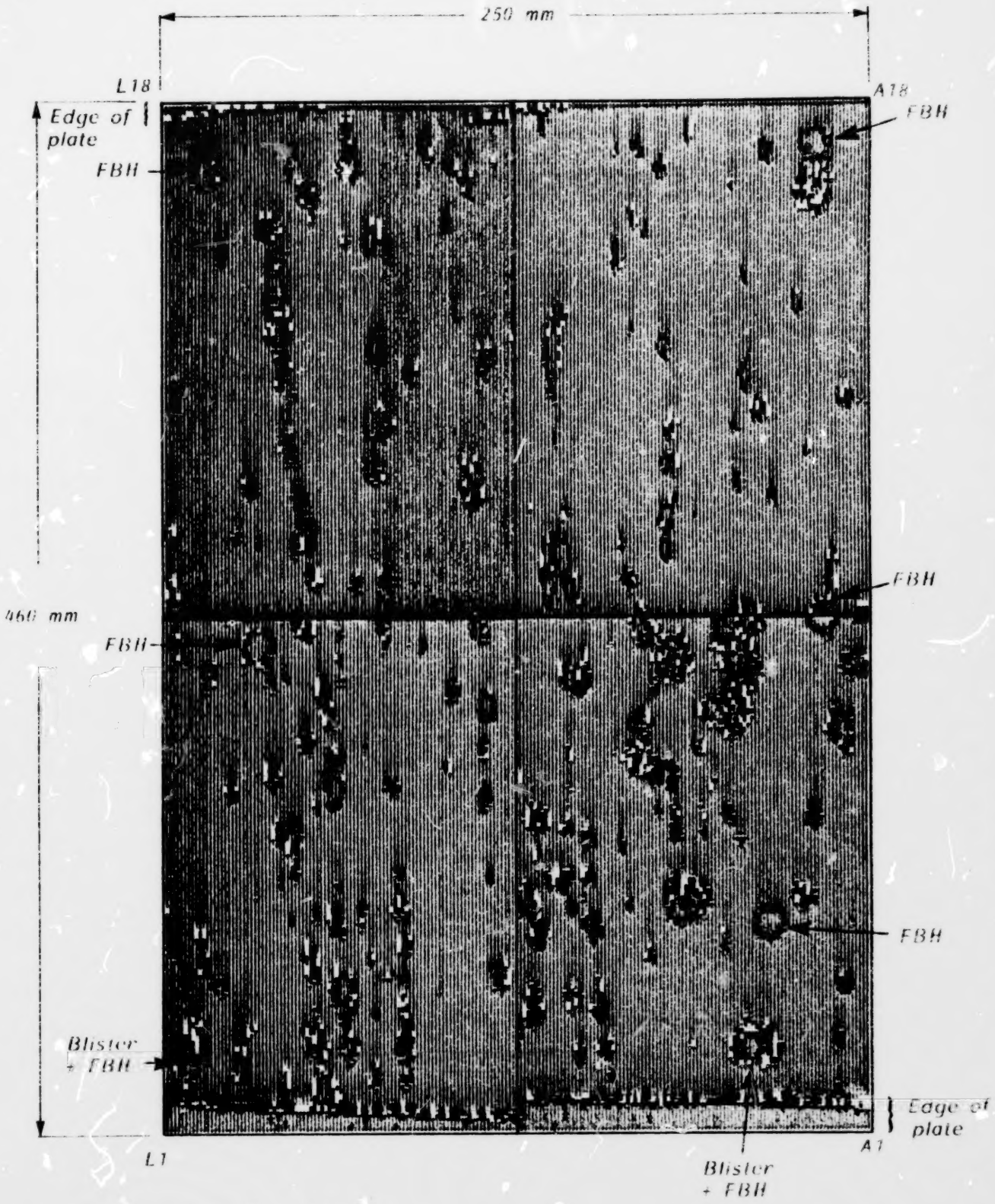

FIGURE 11

C-SCAN OF GRID REGION ON PLATE F, SHOWING MARKERS AND EXTENSIVE BLISTERING

174570-RD

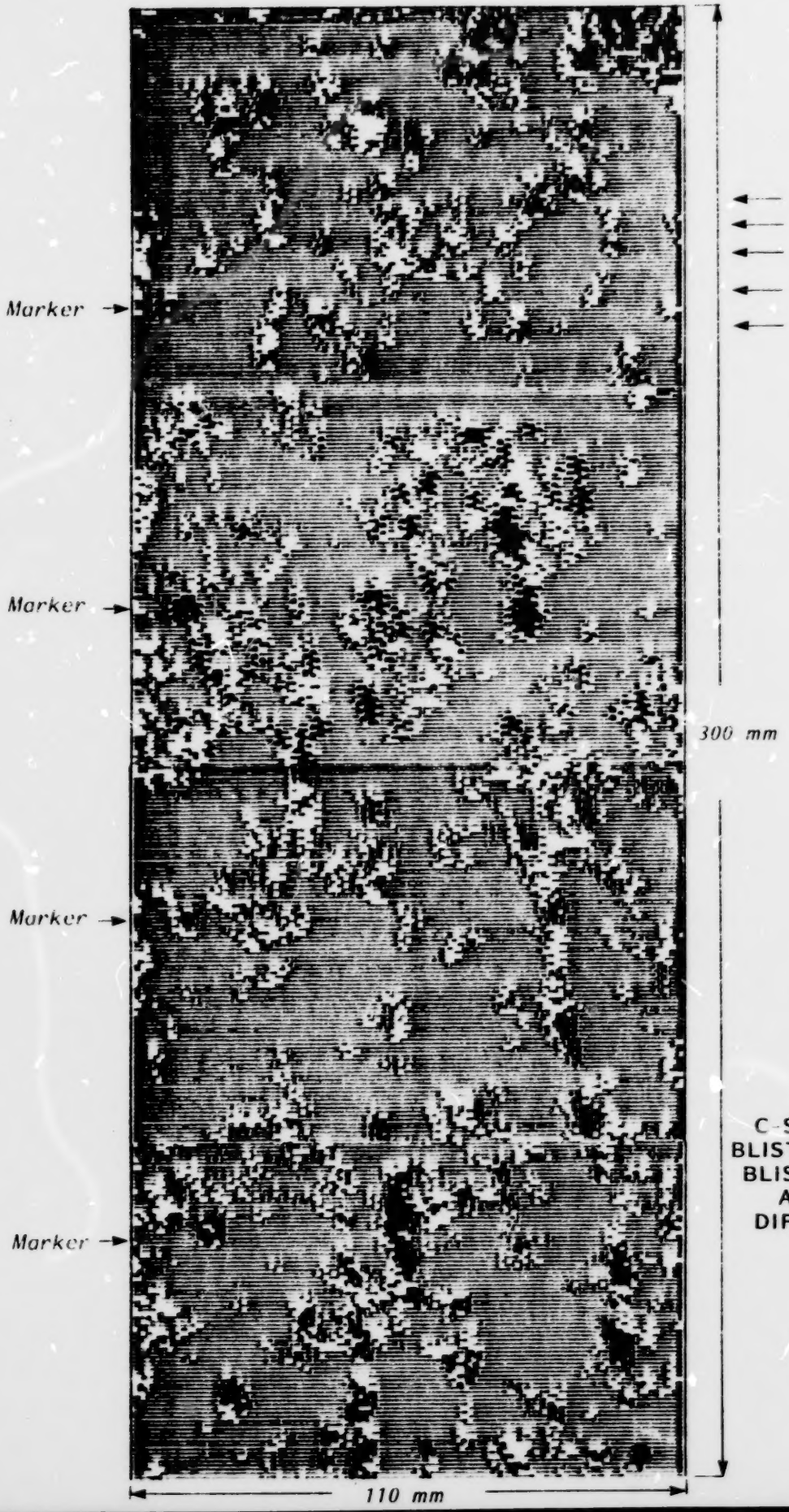

FIGURE 12

C-SCAN OF RESEARCH BLISTERED PLATE, SHOWING BLISTERS IN BLUE, RED AND WHITE. (NOTE DIFFERENT SCALE TO FIGURES 5-11)

174571-RD

FIGURE 13

LOSS OF BACKWALL SCAN OF RESEARCH PLATE. GREEN AREAS INDICATE LOSS OF BACKWALL SIGNAL (ie) POSSIBLE PRESENCE OF BLISTERS

174572-RD

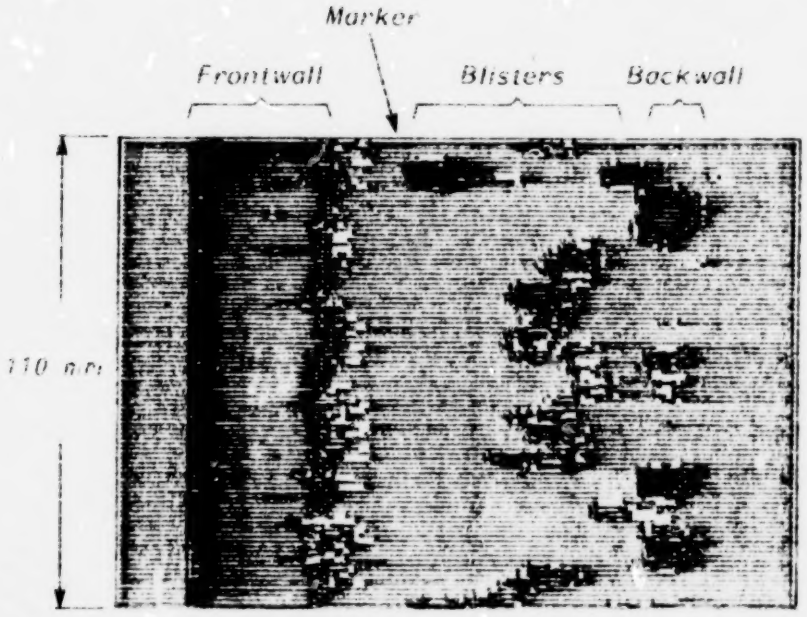

FIGURE 14

SAMPLE B SCAN ON RESEARCH PLATE,
SHOWING EXTENSIVE BLISTERING
AND STEP WISE CRACKING

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